Observational & Modeling Studies in Support of the Atlantic Stratocumulus Transition Experiment

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Grant Number N00014-91-J-1422, P00008
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LONG-TERM GOALS

Our long-term goal is unchanged from last year. It is to learn how to predict the cloudiness, entrainment rate, and turbulent fluxes in the marine boundary layer under any and all large-scale conditions. In particular the effects of varying sea surface temperature, varying inversion strength, and varying mean winds must be included. The cloudiness types encompassed include fog, stratus, stratocumulus, and shallow cumulus clouds, with or without mesoscale organization.

OBJECTIVES

Our efforts are concentrated on the roles of cloud top cooling due to radiation and evaporation. These processes drive down drafts in the marine boundary layer (MBL) which in turn affect the evolution of the MBL cloud layer and its subsequent radiative properties.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **Observational & Modeling Studies in Support of the Atlantic Stratocumulus Transition Experiment**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Colorado State University ,Department of Atmospheric Science,Fort Collins,CO,80523-1371**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

Our approach is a combined theoretical/experimental. We are making use of data from FIRE, ASTEX, and BOMEX to test our theories. We are using numerical models to make connections between the theory and the data. We are testing our ideas using the results of large eddy simulations (LES) performed by our colleague Dr. Chin-Hoh Moeng, of NCAR. We are also developing new techniques and methodologies to observe important radiative properties of the MBL.

WORK COMPLETED

(1) Rawinsonde data and model-generated radiative heating profiles have been used to investigate vertical distributions of the apparent heat source and apparent moisture sink from ASTEX (Atlantic Stratocumulus Transition Experiment) for the period 1-15 June 1992. The budget computations used the methods described in Yanai et al. (1973) and Nitta and Esbensen (1974a). The radiative divergence estimates were made for the ASTEX region using NCAR's community radiation model in conjunction with sounding data and a simple procedure to define cloud boundaries and liquid water content. Using budget computations of apparent heat source and moisture sink along with model generated radiative profiles; we analyzed the vertical eddy flux of moist static energy.

(2) The design, fabrication and testing of computer controlled solar tracker has been completed. This solar tracking device with the capacity to assimilate tracking error corrections in order to improve future tracking performance will be very useful in field experiments.

RESULTS

(1) Analysis of rawinsonde data and model derived radiative heater profiles has shown that the temporal variability of apparent heating and moistening profiles over ASTEX were strongly modulated on a synoptic time scale by the passage of fronts and fluctuations in the subsidence rate related to changes in the strength and position of the subtropical high.

During the 1-15 June period over the ASTEX triangle, fractions low cloudiness averaged 46% with a large synoptic variability in which cloud amount frequently changed by more that 20% on a time scale of a day or less. Relationships between changes in low cloud amount and fluctuations in large-scale budgets are often tenuous, considering that cloud maintenance involves complex feedbox between radiation, microphysics, surface fluxes and convection (Bretherton et al.~1995). Nevertheless, from the ASTEX cloudiness time series we observed that the two largest increases in low cloud amount over this region occurred coincidentally with periods of reduced large-scale subsidence and were preceded by a period of enhanced convective fluxes which served to moisten the inversion layer.

The ASTEX mean radiative profile shows cooling throughout the troposheric column, maximizing in a 500 m deep layer centered near the mean inversion base at a rate of –3 K/day.

The ASTEX mean profile of vertical eddy flux decreases from its surface maximum of 125 W/m^2 to about 10% of this value at 2 km.

(2) During the past year we have made a lot of progress in the development and testing of a new marine boundary layer model which can represent both stratocumulus and shallow cumulus regimes. We have tested the model using data from the Willis-Deardorff laboratory tank experiments, as well as field data from BOMEX, ATEX, and ASTEX. The attached figures show the vertical velocity variance and cloud liquid water in a simulation of BOMEX (Lappen et al., 1999). The "Pulses" represent shallow convective cloud formation. Analysis of these and many additional model results has led to improved understanding of how and why buoyancy effects tend to produce narrow updrafts when a layer is heated from below, and narrow downdrafts when the layer is cooled from above. Cloud processes enhance these tendencies.

We have also begun an observational study of the relationship between tropical cyclone genesis and the prevalence of deep convection (Tulich and Kimberlain, 1999). The data show that tropical cyclogenesis is favored in regions of frequent deep cumulus convection as observed by satellite. The data show that the spatial organization of the convective region has a strong effect on the probability of tropical cyclone formation.

(3) Tracking errors were assessed for a computer controlled solar tracker developed in the previous years. The effects of optical scattering on radiometric measurements performed with the tracker were also evaluated. As the position of the tracker is iteratively corrected over time, linear regression is used to calculate a best-fit correction for tracking error. The performance of the tracker was found to be sensitive to the timing of the iterative corrections and to the errors associated with those corrections. Using an optimized scheme for iterative corrections in a field test, the average tracking error was found to be 0.11 ± 0.05 degrees for 48 hours following the final iterative correction.

IMPACT/APPLICATIONS

The boundary layer simulations will provide better, validated representations boundary layer mass, energy and momentum transfer. These representations will then be available to utilize in many different time and space scales of MBL prediction models.

The semi-automated, self-correcting solar tracker is useful in both research and operational settings in which continuous sight of the solar disc, and absolute, accurate directional information are not available.

TRANSITIONS

The semi-automated, self-correcting solar tracker is being utilized by several research groups who do experimental research on atmospheric boundary layer energy and water mass transports. There is the possibility that this tracking system would be very useful in operational deployments as well.

RELATED PROJECTS

The principal investigators are involved in boundary layer studies in other geographical areas. Professor Randall is a principal in the SHEBA experiment; his studies are concentrating on the boundary layer structure over the Arctic Sea ice sheet. Professor Cox is working with the CSU Geosciences Center investigating multi-layered cloud systems over continental areas.

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PATENTS

None.

IN-HOUSE/OUT-OF-HOUSE RATIOS

One hundred percent of this work is done by CSU, an academic institution.

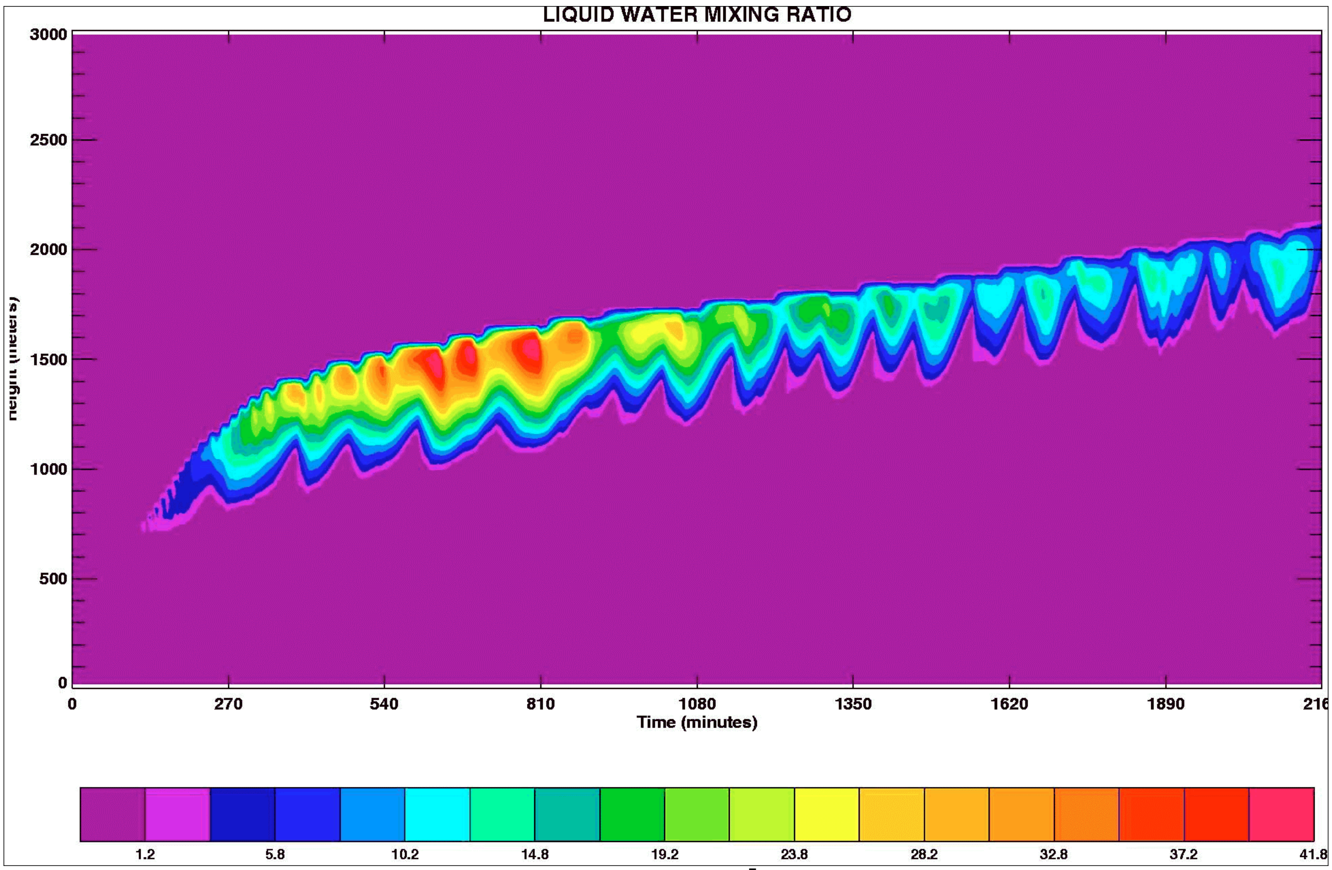

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Figure 1. Evolution of liquid water content of the MBL derived from simulation of BOMEX environmental conditions.

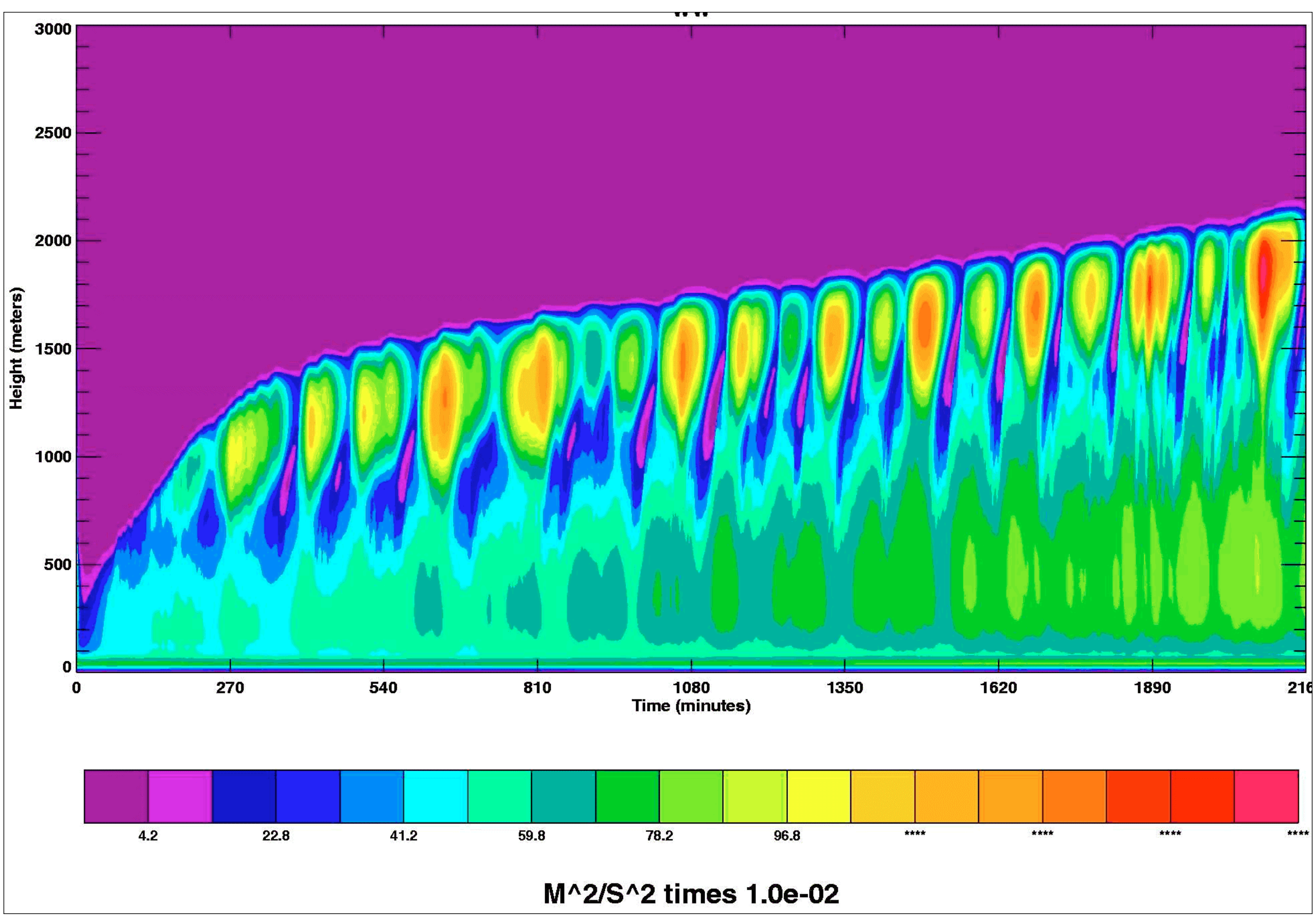

Figure 2. Evolution of the vertical velocity variance in the MBL derived from a simulation of BOMEX environmental conditions.